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Perenniporia koreana, a new wood-rotting basidiomycete from South Korea

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Abstract — A new *Perenniporia* species, *P. koreana,* is described based on morphological and molecular data from specimens collected from Gyeonggi-do and Gangwon-do, Korea. It is characterized by annual resupinate basidiocarps that are very pale brown to yellow when dry. Microscopically, it has a dimitic hyphal system with dextrinoid and cyanophilous skeletal hyphae, and its basidiospores are ellipsoid, hyaline, thick-walled, smooth, dextrinoid, cyanophilous, (5.9–)6–7(–7.5) × (3.7–)3.9–5.2(– 5.7) µm.

Key words —phylogeny, *Polyporaceae*, polypore, taxonomy

Introduction

Perenniporia Murrill is a polypore genus of wood-rotting fungi. The characteristics of this genus are: (1) annual to perennial, resupinate to pileate basidiocarps; (2) dimitic to trimitic hyphal system with clamped generative hyphae and non-dextrinoid to strongly dextrinoid or amyloid vegetative hyphae; and (3) usually thick-walled, ellipsoid to truncate, variably dextrinoid or amyloid basidiospores (Gilbertson & Ryvarden 1987; Zhao & Cui 2013a,b). There are about 90 *Perenniporia* species reported in the world and this genus was shown to be polyphyletic when evolutionary relationships were inferred from the representative *Perenniporia* species including the type, *P. medulla-panis* (Jacq.) Donk (Robledo et al. 2009; Zhao et al. 2013; Zhao & Cui 2013a,b).

In Korea, nine *Perenniporia* species have been recorded: *P. fraxinea* (Bull.) Ryvarden, *P. fraxinophila* (Peck) Ryvarden, *P. medulla-panis*, *P. minutissima* (Yasuda) T. Hatt. & Ryvarden, *P. ochroleuca* (Berk.) Ryvarden, *P. ohiensis* (Berk.) Ryvarden, *P. subacida* (Peck) Donk, *P. tephropora* (Mont.) Ryvarden, and *P. truncatospora* (Lloyd) Ryvarden (Lee & Jung 2005; Park & Lee 2011). During research on indigenous fungi in South Korea, we found eight specimens that represent *Perenniporia* but had characteristics that deviated from the previously reported species. Based on morphological and molecular analyses, we describe them as a new species.

Materials & methods

Collection and morphological examination

Eight *Perenniporia* specimens collected from Gyeonggi-do and Gangwon-do in Korea were used in this study. We examined them macro- and microscopically according to Jang et al. (2013). Spores were measured in Melzer's reagent and 5% of the measurements from both ends are presented in parentheses (Zhao & Cui 2013a). Color codes follow Munsell (2009). The studied specimens have been deposited at the Herbarium of National Institute of Biological Resources, Korea (KB).

Phylogenetic analysis

Genomic DNA was extracted from the specimens according to Jang et al. (2012). PCR reactions were primed with ITS1F (Gardes & Bruns 1993) / ITS4 (White et al. 1990) for internal transcribed spacer (ITS) region and with LR0R/LR7 (Vilgalys & Hester 1990) for nuclear large subunit ribosomal DNA (nLSU) region according to Jang et al. (2012). DNA was sequenced by Macrogen DNA sequencing service (Seoul, Korea), and the sequences were deposited in GenBank, NCBI. The ITS and nLSU sequences of closely related species were retrieved from GenBank. The sequences were aligned with MAFFT 7.130 (Katoh & Standley 2013) using the L-INS-i method for each dataset. For Bayesian analysis, the best-fit model for each dataset was calculated by MrModeltest 2.3 (Nylander 2004) under AIC criterion. The two datasets were combined and the selected models were applied. The 50% majority rule consensus tree was calculated by MrBayes 3.2 (Ronquist et al. 2012) according to Jang et al. (2013).

Taxonomy

Perenniporia koreana Y. Jang & J.J. Kim, **sp. nov.** FIG. 1

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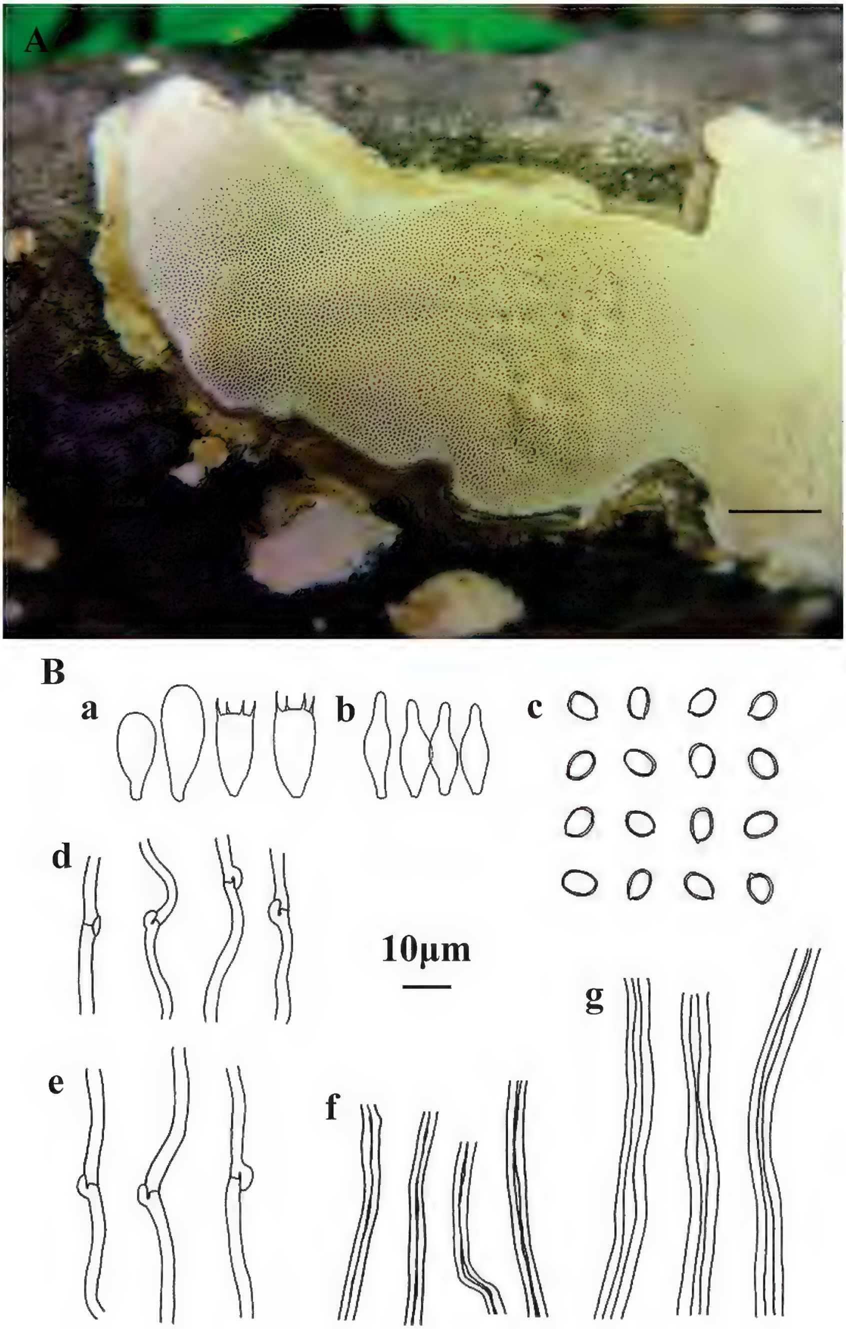
> Differs from other *Perenniporia* species by its annual resupinate basidiocarps with grayish orange pore surface, lack of rhizomorphs in most specimens, a dimitic hyphal system with dextrinoid skeletal hyphae, and ellipsoid non-truncate dextrinoid basidiospores.

FIG. 1. *Perenniporia koreana* (KB NIBRFG107080, holotype). A. Basidiocarp. Scale bar = 1 cm. B. Microscopic features: a, basidioles and basidia; b, cystidioles; c, basidiospores; d, generative hyphae from trama; e, generative hyphae from context; f, skeletal hyphae from trama; g, skeletal hyphae from context.


A
B
a
b
c
d
e
f
g
10µm

Type: Korea. Kyeonggi-do, Dongducheon-si, Mt. Soyo, 37°56′44″N 127°04′08″E, on the branch of *Quercus* sp., 17 May 2008, Jae-Jin Kim KUC20080517-15 (**Holotype**, KB NIBRFG107080; GenBank KJ156301, KJ156309).

Etymology: The locality (Korea) of the type specimen.

Basidiocarps annual, resupinate, adnate, ca. 8.5 cm or more in longest dimension, ca. 4 cm in widest dimension. Sterile margin felty, orange gray (10YR8/2), up to 1 cm wide, usually without rhizomorphs (present only in KB NIBRFG107396). Pores round to angular, 5–6 per mm; dissepiments thin, entire; pore surface grayish orange (10YR8/3-8/4) to brownish orange (10YR7/6-7/8) in dried condition. Context corky, cream to buff, up to 0.5 mm thick. Tubes corky, concolorous with pore surface, up to 2 mm thick.

Hyphal system dimitic; generative hyphae with clamp connections; skeletal hyphae dextrinoid, cyanophilous.

Context generative hyphae hyaline, thin-walled, 1.5–3 µm in diameter; skeletal hyphae dominant, hyaline, thick-walled, with a distinct lumen, interwoven, 3.5–6 µm in diameter.

Tubes generative hyphae hyaline, thin-walled, 1.5–2.5 µm in diameter; skeletal hyphae dominant, hyaline, thick-walled, with a narrow lumen to subsolid, rarely branched, interwoven, 1.5–4.5 µm in diameter. Cystidia absent, fusoid cystidioles present, 19.5–23 × 5–6.5 µm; basidia barrel-shaped, 4 sterigmate, 21–23 × 7.5–9 µm.

Basidiospores ellipsoid, hyaline, thick-walled, smooth, dextrinoid, cyanophilous, (5.9–)6–7(–7.5) × (3.7–)3.9–5.2(–5.7) µm, L = 6.56, W = 4.45 (n = 120/4).

Ecology & distribution — Korea, on hardwoods causing white rot.

Additional specimens examined: **KOREA, Kyeonggi-do,** Uijeongbu-si, Mt. Dobong, on fallen wood branch, 30 October, 2009, Yeongseon Jang KUC20091030-32 (KB NIBRFG113564; GenBank KJ156305, KJ156313); Yongin-si, Mt. Gwanggyo, 37°21′05″N 127°03′14″E, on hardwood, 14 August 2012, Yeongseon Jang KUC20120814-17 (KB NIBRFG125415; GenBank KJ156306, KJ156314); Yangju-si, Mt. Goryeong, on wood, 11 July 2009, Yeongseon Jang KUC20090711-70 (KB NIBRFG113613; GenBank KJ156304, KJ156312); Dongducheon-si, Mt. Soyo, 37°56′44″N 127°04′08″E, on the branch of hardwood, 17 May 2008, Jae-Jin Kim KUC20080517-02 (KB NIBRFG107071; GenBank KJ156300, KJ156308); **Gangwon-do,** Heongseong-gun, Mt. Chiak, on wood, 4 April 2009, Young Woon Lim KUC20090404-27 (KB NIBRFG113243; GenBank KJ156303, KJ156311); 37°20′16″N 128°03′27″E, on hardwood, 2 October 2008, Jae-Jin Kim KUC20081002J-02 (KB NIBRFG107396; GenBank KJ156302, KJ156310); Wonju-si, Mt Chiak, 37°21′43″N 128°02′36″E, on the branch of *Quercus* sp., 10 May 2008, Jae-Jin Kim KUC20080510-01 (KB NIBRFG107760; GenBank KJ156299, KJ156307).

Phylogeny

The combined ITS+nLSU dataset contained 56 taxa and 2016 characters, of which the ITS dataset was 667 characters and nLSU was 1349 characters. By the

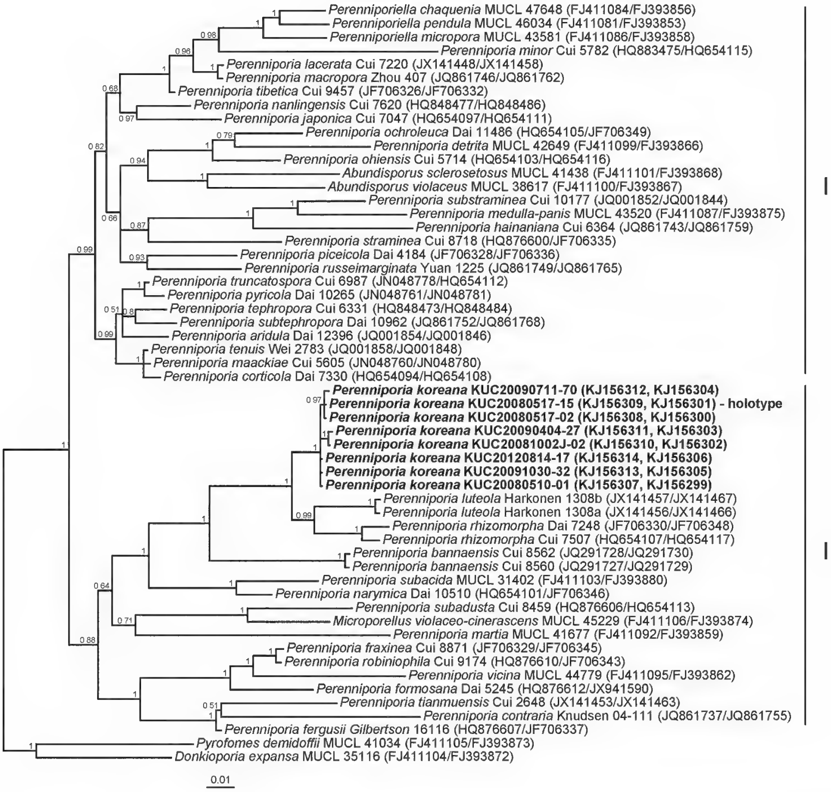

Perenniporiella chaquenia MUCL 47648 (FJ411084/FJ393856)
Perenniporiella pendula MUCL 46034 (FJ411081/FJ393853)
Perenniporiella micropora MUCL 43581 (FJ411086/FJ393858)
Perenniporia minor Cui 5782 (HQ883475/HQ654115)
Perenniporia lacerata Cui 7220 (JX141448/JX141458)
Perenniporia macropora Zhou 407 (JQ861746/JQ861762)
Perenniporia tibetica Cui 9457 (JF706326/JF706332)
Perenniporia nanlingensis Cui 7620 (HQ848477/HQ848486)
Perenniporia japonica Cui 7047 (HQ654097/HQ654111)
Perenniporia ochroleuca Dai 11486 (HQ654105/JF706349)
Perenniporia detrita MUCL 42649 (FJ411099/FJ393866)
Perenniporia ohiensis Cui 5714 (HQ654103/HQ654116)
Abundisporus sclerosetosus MUCL 41438 (FJ411101/FJ393868)
Abundisporus violaceus MUCL 38617 (FJ411100/FJ393867)
Perenniporia substraminea Cui 10177 (JQ001852/JQ001844)
Perenniporia medulla-panis MUCL 43520 (FJ411087/FJ393875)
Perenniporia hainaniana Cui 6364 (JQ861743/JQ861759)
Perenniporia straminea Cui 8718 (HQ876600/JF706335)
Perenniporia piceicola Dai 4184 (JF706328/JF706336)
Perenniporia russeimarginata Yuan 1225 (JQ861749/JQ861765)
Perenniporia truncatospora Cui 6987 (JN048778/HQ654112)
Perenniporia pyricola Dai 10265 (JN048761/JN048781)
Perenniporia tephropora Cui 6331 (HQ848473/HQ848484)
Perenniporia subtephropora Dai 10962 (JQ861752/JQ861768)
Perenniporia aridula Dai 12396 (JQ001854/JQ001846)
Perenniporia tenuis Wei 2783 (JQ001858/JQ001848)
Perenniporia maackiae Cui 5605 (JN048760/JN048780)
Perenniporia corticola Dai 7330 (HQ654094/HQ654108)
Perenniporia koreana KUC20090711-70 (KJ156312, KJ156304)
Perenniporia koreana KUC20080517-15 (KJ156309, KJ156301) - holotype
Perenniporia koreana KUC20080517-02 (KJ156308, KJ156300)
Perenniporia koreana KUC20090404-27 (KJ156311, KJ156303)
Perenniporia koreana KUC20081002J-02 (KJ156310, KJ156302)
Perenniporia koreana KUC20120814-17 (KJ156314, KJ156306)
Perenniporia koreana KUC20091030-32 (KJ156313, KJ156305)
Perenniporia koreana KUC20080510-01 (KJ156307, KJ156299)
Perenniporia luteola Harkonen 1308b (JX141457/JX141467)
Perenniporia luteola Harkonen 1308a (JX141456/JX141466)
Perenniporia rhizomorpha Dai 7248 (JF706330/JF706348)
Perenniporia rhizomorpha Cui 7507 (HQ654107/HQ654117)
Perenniporia bannaensis Cui 8562 (JQ291728/JQ291730)
Perenniporia bannaensis Cui 8560 (JQ291727/JQ291729)
Perenniporia subacida MUCL 31402 (FJ411103/FJ393880)
Perenniporia narymica Dai 10510 (HQ654101/JF706346)
Perenniporia subadusta Cui 8459 (HQ876606/HQ654113)
Microporellus violaceo-cinerascens MUCL 45229 (FJ411106/FJ393874)
Perenniporia martia MUCL 41677 (FJ411092/FJ393859)
Perenniporia fraxinea Cui 8871 (JF706329/JF706345)
Perenniporia robiniophila Cui 9174 (HQ876610/JF706343)
Perenniporia vicina MUCL 44779 (FJ411095/FJ393862)
Perenniporia formosana Dai 5245 (HQ876612/JX941590)
Perenniporia tianmuensis Cui 2648 (JX141453/JX141463)
Perenniporia contraria Knudsen 04-111 (JQ861737/JQ861755)
Perenniporia fergusii Gilbertson 16116 (HQ876607/JF706337)
Pyrofomes demidoffii MUCL 41034 (FJ411105/FJ393873)
Donkioporia expansa MUCL 35116 (FJ411104/FJ393872)
I
II
0.01

FIG. 2. 50% majority consensus tree of *Perenniporia koreana* and allied species inferred from combined ITS+nLSU region sequences. Posterior probabilities over 0.5 are shown above branches. GenBank accession numbers are presented in parentheses (ITS/nLSU). *Perenniporia koreana* is indicated by bold type.

model selection, GTR+I+G model was chosen for both ITS and nLSU datasets. *Pyrofomes demidoffii* (Lév.) Kotl. & Pouzar (MUCL 41034) and *Donkioporia expansa* (Desm.) Kotl. & Pouzar (MUCL 35116) were used as outgroup (Zhao & Cui 2013a,b; Zhao et al. 2013). The phylogenetic tree (FIG. 2) provides the sequence information for the included taxa. Our analysis supported two main groups, I and II. Group I, which contained *Perenniporia* species with typically truncate basidiospores, included *P. medulla-panis* (the type species) as well as *Abundisporus sclerosetosus* Decock & Laurence, *A. violaceus* (Wakef.) Ryvarden, *Perenniporiella chaquenia* Robledo & Decock, *P. pendula* Decock & Ryvarden, and *P. micropora* (Ryvarden) Decock & Ryvarden. Group II included

Perenniporia species with non-truncate basidiospores (except for *P. fergusii* Gilb. & Ryvarden with ellipsoid to slightly truncate basidiospores; Gilbertson & Ryvarden 1987), and *Microporellus violaceocinerascens* (Petch) A. David & Rajchenb. *Perenniporia koreana* was in group II and monophyletic with high posterior probability value (1.0 p.p.). Its sister taxa were *P. luteola* B.K. Cui & C.L. Zhao and *P. rhizomorpha* B.K. Cui et al., and these three taxa clustered with *P. bannaensis* B.K. Cui & C.L. Zhao, *P. subacida*, and *P. narymica* (Pilát) Pouzar in a clade with high support (1.0 p.p.).

Discussion

Morphologically, *Perenniporia koreana* is very similar to its sister taxa, *P. luteola* and *P. rhizomorpha,* which are also characterized by a resupinate basidiocarp, yellowish pore surface, dextrinoid skeletal hyphae, and dextrinoid non-truncate basidiospores. However, *P. luteola* differs by its perennial habit and slightly wider basidiospores (6.1–6.9 × 5.1–5.4 µm; Zhao & Cui 2013a), and *P. rhizomorpha* differs by having typical rhizomorphs, slightly longer basidiospores (5.3–6.5 × 4.1–5.2 µm), contextual skeletal hyphae encrusted with fine crystals and lacking cystidia and cystidioles (Cui et al. 2007).

Perenniporia tenuis (Schwein.) Ryvarden and *P. bannaensis* are similar to *P. koreana* in their annual resupinate basidiocarps, yellowish pore surface, dimitic hyphal system with dextrinoid skeletal hyphae, fusoid cystidioles, and dextrinoid basidiospores. However, *P. tenuis* differs in its larger pores (3–5/mm) and small ellipsoid to truncate basidiospores (4.5–6 × 3.5–4.5 µm; Ryvarden & Gilbertson 1994), while *P. bannaensis* differs in its small pores (6–8/mm), entire to lacerate dissepiments, and shorter basidiospores (5.2–6 × 4–4.6 µm; Zhao et al. 2013).

Phylogenetically (Fig. 2), the species relationships in our analysis differ substantially from those of Zhao et al. (2013) and Zhao & Cui (2013a,b). Our analysis clustered *Perenniporia luteola, P. rhizomorpha,* and *P. bannaensis* in group II, a relationship also observed when *P. koreana* was excluded from the phylogenetic analysis (not shown). In contrast, *P. rhizomorpha* and *P. bannaensis* were monophyletic with *P. medulla-panis* in Zhao et al. (2013); and *P. luteola, P. rhizomorpha,* and *P. bannaensis* clustered with *P. medulla-panis* in Zhao & Cui (2013a,b). Further research with additional loci would help to resolve the species relationships of *Perenniporia.*

In conclusion, we propose *Perenniporia koreana* as a new species with only minute morphological distinction but with distinct genetic differences.

Acknowledgments

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